63-2-4

TECHNICAL BULLETIN 62-16

TRAINING, UTILIZATION, AND PROFICIENCY OF NAVY ELECTRONICS TECHNICIANS

IV. PROFICIENCY IN MATHEMATICS

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151 100

OCTOBER 1962

$3.60

BUREAU OF NAVAL PERSONNEL

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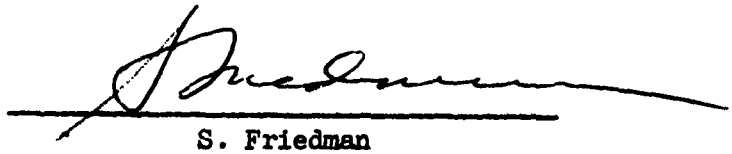

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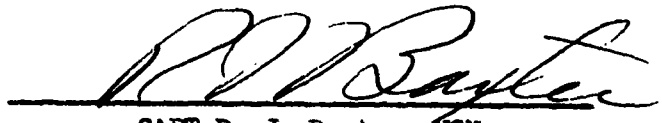

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BRIEF

This is the fourth of a seven-report series based on the results of a major survey of the training, utilization, and proficiency of Navy Electronics Technicians (ET's) which was conducted in the Pacific Fleet and the western United States during the first half of 1961.

A Mathematical Achievement Test designed to measure basic abilities in powers-of-ten, square root, algebra, logarithms, trigonometric functions, and binary arithmetic was developed and included in the survey. All of the twenty-six items in the test were open-ended--that is, in no case was a set of answers provided from which to choose the correct one.

Results tend to support the opinions of those who contend that ET's, in general, lack proficiency in mathematics. From 42% to 63% of the powers-of-ten, square root, and algebra items and from 6% to 14% of the logarithms, trigonometric functions, and binary arithmetic items were answered correctly (p. 6).

A factor analysis of interrelationships among forty-seven survey variables, including the six Mathematical Achievement Test scores, is presented in Appendix B. Mathematical Achievement Test scores were found to be related to Class "A" school marks (p. 8) but not to any measure of ET job proficiency included in this study (p. 10). It is concluded that no ET job performance requirement for greater mathematical capability has been revealed.

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TABLES

TRAINING, UTILIZATION, AND PROFICIENCY OF NAVY ELECTRONICS TECHNICIANS

IV. PROFICIENCY IN MATHEMATICS

A. BACKGROUND

This is the fourth report in a series resulting from a survey of the training, utilization, and proficiency of Electronics Technicians (ET's) assigned to the United States Pacific Fleet and to naval commands in the Eleventh, Twelfth, and Thirteenth Naval Districts. The first report (1) dealt with such general considerations as sampling, instrumentation, and data collection procedures and presented descriptive statistics on such variables as age, education, classification test scores, billet and assignment types, training received and stated training needs. The second report (2) was concerned with technical experience and proficiency; it reflected information obtained from the Equipment Experience Check List and the Performance Check List used in the survey. In the third report (3) results of the administration of a test equipment performance test were analyzed.

During planning stages of the ET survey, individuals concerned with ET training often expressed the opinion that ET's need more training in mathematics. The areas of mathematics most often mentioned were powers-of-ten, square root, algebra, logarithms, trigonometry, and binary arithmetic. A simple test was constructed to measure basic abilities in these areas. This fourth report in the ET series is concerned with the results of the administration of the mathematics achievement test and the relationships of those results to other variables.

B. THE TEST AND PROCEDURES

1. The Test

The items in the Mathematical Achievement Test were intended to be simple and only to measure basic abilities in the six subtest areas. A preliminary form of the test was developed, administered to a pilot sample, and modified to remove ambiguities and to reduce test length. The number of items in each subtest was kept very low so that the total test could be completed in approximately thirty minutes. The final test included eight powers-of-ten items (two each involving addition, subtraction, multiplication, and division), three square root items, five algebra items, three logarithm items, three trigonometry items, and four binary arithmetic items for a total of twenty-six. All items were open ended--that is, in no case was a set of answers provided from which to choose the correct one. A copy of the test with its accompanying instructions appears in Appendix A.

2. Administration

Each ET who took the test was provided with a test booklet which included instructions and the test items, a log log decimal trig slide rule, a book of mathematical tables which included five-place logarithms and trigonometric functions, scratch paper, and an answer sheet which provided spaces for recording answers. No time limit was imposed, but most individuals either completed the problems or had decided that they had finished all the problems they were capable of doing within approximately thirty minutes.

3. The Sample

As has been explained earlier (1), the ET survey covered two samples, one from the Pacific Fleet (PACFLT) and one drawn from ET's assigned to the Eleventh, Twelfth, and Thirteenth Naval Districts (CONUS). However, since it seems that little would be gained from treating the Mathematical Achievement Test data from the two samples separately, for this report the two groups will be combined into a single sample of 415 ET's.

C. RESULTS

1. Item and Subtest Results

Table 1 shows the proportion of the 415 ET's who answered each item correctly. With the exception of item 3, p values (proportion answering correctly) for the powers-of-ten items range from .39 to .76. Item 3, which has a p value of .10, required that 14×10^{-2} be subtracted from 12×10^{-3}. This is the only problem in addition or subtraction where the 10's have negative exponents. Of the two multiplication items, item 6, which involves a negative exponent, is somewhat more difficult than item 5 where both of the exponents are positive. Item 7, a division problem involving a negative exponent, is considerably more difficult than item 8 where both of the exponents of ten are positive. In general, it seems that about half of the responses to powers-of-ten items were correct with those items involving negative exponents proving to be more difficult than items where the 10's have only positive exponents.

The p values for the three square root items range from .54 to .72. Item 9 involved a three-digit number, item 10 four digits, and item 11 five digits; the p values of the items in this order were .72, .62, and .54. The accuracy of solutions for square root problems appears to decrease as the magnitude of the number for which the root is desired increases.

TABLE 1

Portion of Correct Responses, By Item,
For Mathematical Achievement Test

Subtest Area	Test Item Number	Proportion of Sample Answering Item Correctly (p)
Powers-of-Ten	1	.52
	2	.48
	3	.10
	4	.56
	5	.76
	6	.61
	7	.39
	8	.61
Square Root	9	.72
	10	.62
	11	.54
Algebra	12	.64
	13	.27
	14	.14
	15	.80
	16	.24
Logarithms	17	.12
	18	.10
	19	.07
Trigonometry	20	.11
	21	.10
	22	.07
Binary Arithmetic	23	.08
	24	.06
	25	.07
	26	.06

The five algebra problems ranged in p values from .14 to .80. The most difficult algebra problem, item 14 which has a p value of .14, is a literal equation in one unknown in which the unknown appears on both sides of the equals sign and in both cases in the denominator of a fraction. Item 15, a very elementary problem in one unknown ($4X + 3 = 15$. Solve for X) has a p value of .80. The following item presents a pair of simple linear equations with two unknowns ($4X + 3Y = 29$; $2X - 6Y = 12$. Solve for X and Y). The p value here drops to .24. Algebra can cover a wide range of subject matter and difficulty; the items presented in this test are only a very small number of examples of linear equations. Except for the most elementary equations in one unknown, performance by this sample of ET's was quite poor.

The p values for the logarithm and trigonometry items ranged from .07 to .20. This means that the easiest of these items was answered correctly by only one ET out of five. It is clear that, in general, ET's do not have a working knowledge of logarithms or trigonometric functions.

It was expected that few ET's would have a knowledge of binary arithmetic. This expectation was verified. The p values for the four items in this area ranged from .06 to .08. Those who were able to solve one of the binary arithmetic problems correctly usually were able to answer most of them correctly. Binary arithmetic is probably not a difficult area to master, but it does demand special training.

Table 2 presents the means and standard deviations for the subtest and total test scores.

2. Relationships Among Scores

Table 3 presents the intercorrelations among the various scores on the Mathematical Achievement Test. With the exception of those involving the total test score, the correlation coefficients in Table 3 are low to moderate in size, ranging from .11 to .45. The lowest correlation (.11) is between square root and binary arithmetic, and the highest correlations (.45) are between powers-of-ten and algebra and between logarithms and trigonometric functions. The generally low magnitude of the correlation coefficients probably is mainly a function of two considerations, the small number of items in each subtest and differences in content among the subtests.

TABLE 2

Means and Standard Deviations for
Mathematical Achievement Test Scores

Score	Number of Items	Mean	Standard Deviation	Per Cent Correct
Powers-of-Ten	8	4.03	2.26	50%
Square Root	3	1.88	1.13	63
Algebra	5	2.10	1.40	42
Logarithms	3	.30	.77	10
Trigonometric Functions	3	.41	.83	14
Binary Arithmetic	4	.26	.88	6
Total	26	8.98	4.88	35

TABLE 3

Intercorrelations Among Mathematical Achievement Test Scores

Score:	Square Root	Algebra	Logar-ithms	Trig. Functions	Binary Arith.	Total
Powers-of-Ten	37	45	29	32	22	82
Square Root		36	18	20	11	59
Algebra			40	39	23	75
Logarithms				45	22	56
Trig. Functions					20	59
Binary Arithmetic						44

NOTES:

1. Decimal points have been omitted.

2. With 415 cases, an r of .13 is significantly different from zero at the 1% confidence level.

3. Relationships With Other Survey Variables

The ET survey has produced data on many variables. The relationships of the Mathematical Achievement Test scores to many of these other variables is of interest. Discussions and interpretations of the interrelationships among a large number of variables can become exceedingly complex if a statistical index, such as the correlation coefficient, that measures relationships between pairs of variables is employed directly. To simplify data interpretation, a factor analysis was performed on a matrix of intercorrelations among 47 of the variables considered in the ET survey. The 47 variables included the 17 derived check list scores described in the second report in this series (2), 5 classification test scores, two ratings by supervisors (1), 5 test equipment test scores (including schematic reading) (3), 3 measures of work time from the work diary (1), 9 measures of various background variables such as pay grade and years of education, and the 6 Mathematical Achievement Test scores. The factor analysis accounted for the interrelationships among the 47 variables with 15 factors. The complete factor analysis is presented in Appendix B. Only the 3 factors which involved Mathematical Achievement Test scores will be discussed here. The numbers associated with each of these factors will be the same as those used in Appendix B. Only those factor loadings which equal or exceed .30 in absolute value will be discussed.

Factor II. Proficiency in Mathematics

Variables	Factor Loadings
22 Arithmetic Test score	.42
25 Electronics Tech. Selection Test score	.45
20 Class "A" School mark	.31
34 Powers-of-Ten	.39
36 Algebra	.57
37 Logarithms	.68
38 Trigonometric Functions	.53
39 Binary Arithmetic	.33

This factor has loadings only on tests and school marks. Five of the six Mathematical Achievement subtests have loadings greater than .30. The one subtest not represented here is the one for square root. The largest loading is for logarithms (.68). Both the Basic Test Battery Arithmetic Test and the Electronics Technician Selection Test (which has a substantial mathematics section) appear on this factor. Class "A" School grades have a modest loading of .31. Although the analysis included several measures of job proficiency, none of them appear to be related to this factor.

Factor X. Assignment to Corrective Maintenance Tasks

Variables	Factor Loadings
30 Time in Class "C" Schools	.35
39 Binary Arithmetic	.36
46 Corrective maintenance work time	.53

Variable 46 reflects the amount of time that ET's reported spending on corrective maintenance tasks in a work diary completed during the week following survey interviews. Factor X is not well defined since it has only three loadings, but it appears to indicate that, on the average, ET's who have had special Class "C" type courses spend more time working in corrective maintenance than ET's who have not had or have had less of such training. The binary arithmetic loading on this factor is thought to be coincidental; those who did well on the binary arithmetic test probably had received specialized training in that subject but also probably had had specialized maintenance training.

Factor XIII. Basic Mathematics (Arithmetic)

Variables	Factor Loadings
22 Arithmetic Test score	.36
25 Electronics Tech. Selection Test score	.41
34 Powers-of-Ten	.36
35 Square Root	.46
36 Algebra	.39

All of the variables in this factor except square root are included in Factor II. Factor XIII, however, does not include loadings on the more technical subtests of the Mathematical Achievement Test, such as logarithms and trigonometric functions. Factor XIII seems to measure basic ability in arithmetic since all of the variables in the factor include arithmetic computation. As with Factor II, none of the job proficiency variables appear to be related to this factor.

The factor analysis has indicated that ability in mathematics is related to Class "A" School grades but not to any direct measure of ET job proficiency included in this study. The kinds of mathematics most related to school performance appear to be powers-of-ten, algebra, logarithms, and trigonometric functions.

D. DISCUSSION AND IMPLICATIONS FOR TRAINING

Results of this study have tended to support the opinions of those who contend that ET's, in general, lack proficiency in mathematics. Performance in such areas as powers-of-ten and square root could be considered no better than marginal. In more specialized areas of mathematics such as logarithms and trigonometric functions, average performance was extremely poor. However, the questions should be asked, "What areas of mathematics should ET's have mastered, and why do they need to know these areas?" Several measures of job proficiency were obtained in this study (check list information, supervisors' ratings, job sample measures) but none of them showed any appreciable relationship to differences in mathematical ability. It is possible that work required of ET's could be changed so as to demand more reliance on mathematical ability. However, it is suggested that until some job performance need for mathematics is demonstrated, thinking with regard to mathematics for ET's should be oriented toward deciding what mathematics is needed in order for ET's to study and understand the theoretical materials they will encounter in school or in reading appropriate electronics publications. The question of what electronic theory should be taught or what theory is needed by ET's in order best to perform their jobs is still to be resolved. If current training content is assumed to be appropriate, evidence obtained in this study indicates that training should be provided or emphasized in the areas of powers-of-ten, basic algebra, logarithms, and trigonometric functions. There is considerable evidence, however, (the lack of any significant relationship between mathematics and measures of on-the-job performance) to question the appropriateness of current training content. Apparently, except for the possible value of mathematics training in helping students learn some of the other content of training, mathematics training might be either de-emphasized or specialized, e.g. tied in directly with special training where a particular aspect of mathematics might be required. The apparent need for increased emphasis in training is for direct training on things required on the job such as use of test equipment and maintenance procedures associated with specific equipments. No ET job performance requirement for additional mathematical capability has been revealed.

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1. Anderson, A.V. Training, utilization, and proficiency of Navy Electronics Technicians. I. General considerations, Bureau of Naval Personnel, Technical Bulletin 62-5, March 1962.

2. Anderson, A.V. Training, utilization, and proficiency of Navy Electronics Technicians. II. Technical experience and proficiency, Bureau of Naval Personnel, Technical Bulletin 62-13, September 1962.

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APPENDIX A

MATHEMATICAL ACHIEVEMENT TEST

Instructions: This is a test of your familiarity with certain mathematical concepts. If you are completely unfamiliar with some types of problems, such as logarithms or binary numbers, skip them and continue with other items.

A slide rule and a book of mathematical tables which includes logarithms and trigonometric functions are available and may be used whenever you wish.

Do not write in this booklet. Record your answers on the Answer Sheet and do all your figuring on the scratch paper provided.

Work rapidly.

Add:

1. $(7 \times 10^5) + (13 \times 10^3)$

2. $(1.8 \times 10^4) + (13 \times 10^2)$

Subtract:

3. $(12 \times 10^{-3}) - (14 \times 10^{-2})$

4. $(22 \times 10^6) - (0.022 \times 10^9)$

Multiply:

5. $(16 \times 10^6)(2 \times 10^4)$

6. $(1.8 \times 10^{23})(7 \times 10^{-6})$

Divide:

7. $(81.9 \times 10^4) \div (21 \times 10^{-3})$

8. $(27 \times 10^6) \div (6 \times 10^8)$

Square Root

Find the square roots of the numbers in items 9 through 11. Carry answers to one decimal place, if necessary.

9. 361 10. 5,372 11. 63,504

Algebra

Solve for X:

12. $A = BX^2$

13. $A = \frac{B}{X - A}$

14. $\frac{A}{X} = \frac{B}{X - A}$

15. $4X + 3 = 15$

Solve for X and Y:

16. $4X + 3Y = 29$

$2X - 6Y = 12$

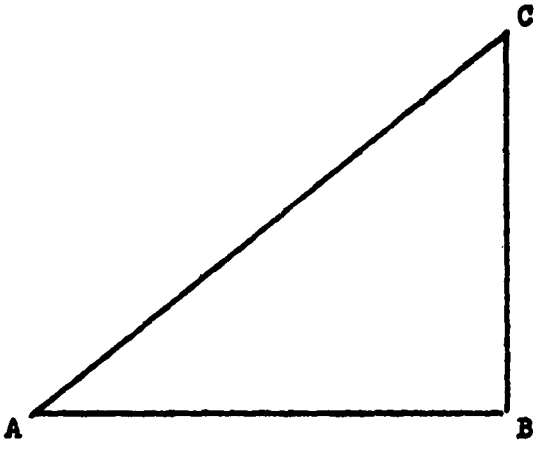
APPENDIX A (continued)

Logarithms

The common logarithm (base = 10) of A is 2.56146 and the logarithm of B is 3.83104. Using the log tables provided, solve for:

17. AB 18. A^2B 19. A ÷ B

Trigonometric Functions



(Use tables of trigonometric functions if you wish.)

Angle B = 90°

Length of side AB = 45

Length of side BC = 35

Find:

20. Angle A 21. cos A 22. Length of side AC

Binary Arithmetic

Both X and Y are binary numbers (numbers to the base 2).

X = 11001 and Y = 101

Solve for the following, giving answers in binary:

23. X + Y 24. X - Y 25. XY 26. X ÷ Y

APPENDIX B

FACTOR ANALYSIS OF INTERCORRELATIONS AMONG ET SURVEY VARIABLES

A factor analysis was performed on the intercorrelations among the 47 ET survey variables listed and identified in Table 4. The Pearson product-moment correlations among the variables are presented in Table 5. A high-speed digital computer was used to extract 15 principal-axis factors. Loadings on the unrotated factors are shown in Table 6. The principal-axis factors were rotated, two at a time, (49 rotations) to simple structure. The rotated factor matrix appears in Table 7.

Some words of caution with regard to the interpretation of this factor analysis are appropriate. From Table 4 it can be seen that the numbers of cases available for computation of correlations is not the same for all pairs of variables since for some ET's information was not available for all variables. The correlation coefficient based on the smallest number of cases is the one between variables 25 and 33, the ETST and the proficiency rating by the supervisor second in line of authority. This correlation is based on 143 cases; all other correlations in the table are based on 200 or more cases. Another possible source of bias lies in the fact that members of the sample were tested on the Navy Basic Test Battery over a period of years and did not all take the same forms of the tests. While in general different forms of a given test are intended to measure the same area, important differences do exist. For example, Form 5 of the Clerical Test is probably more factorially complex than Forms 5F and 6 since the latter two forms involve only comparing pairs of numbers and earlier forms included name comparisons and other item types. Whether or not differences in sample size or differences in test forms have had some biasing effect on results cannot be determined definitely, but any effects they may have had are thought to be slight.

Each of the 15 factors will be presented and discussed briefly. Only factor loadings as large as .30 in absolute value will be considered. In general, the identifying names of variables will be abbreviated.

APPENDIX B (continued)

TABLE 4

Identification of Variables Used in Factor Analysis

Variable Number	Identification	Number of Cases
	Check List Proficiency Scores:	
1	Basic electronic measurement	415
2	Basic troubleshooting and repair	415
3	Computation of electrical/electronic values	415
4	Removal and replacement of basic components	415
5	Maintenance of electronic records	415
6	Radio and teletype POMSEE	415
7	Measurement in communications equipments	415
8	Check, adjust, align, communications equipments	415
9	Troubleshooting & repair of comm. equipments	415
10	Radar and Loran POMSEE	415
11	Measurement in radar equipments	415
12	Check, adjust, align, radar equipments	415
13	Troubleshooting & repair of radar equipments	415
14	Use of an oscilloscope	415
15	Use of a VOM	415
16	Use of a VTVM	415
17	Use of a signal generator	415
18	Pay Grade	415
19	Age	415
20	Total Navy service	415
21	General Classification Test (GCT)	414
22	Arithmetic Test (ARI)	414
23	Mechanical Test (MECH)	414
24	Clerical Test (CLER)	414
25	Electronics Technician Selection Test (ETST)	266
26	Years of education	413
27	ET Experience (logarithm of time)	385
28	"A" School mark	359
29	Time in "A" and "B" Schools	402
30	Time in "C" Schools	412
31	Proficiency pay	410

(Table continued on next page)

TABLE 4 (continued)

Variable Number	Identification	Number Of Cases
32	Proficiency rating by immediate supervisor	381
33	Proficiency rating by supervisor next in line	212
	Mathematical Achievement Test Scores:	
34	Powers of Ten	415
35	Square Root	415
36	Algebra	415
37	Logarithms	415
38	Trigonometric Functions	415
39	Binary Arithmetic	415
	Test Equipment Test Scores:	
40	VOM	415
41	VTVM	415
42	Signal Generator	415
43	Oscilloscope	415
44	Schematic Reading	415
	Time from Work Diary:	
45	Preventive Maintenance	382
46	Corrective Maintenance	382
47	Non-Electronic Duties	382

TABLE 5

Pearson Product-Moment Correlations Among ET Survey Variables

	Variable Numbers															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		76	61	67	53	44	63	62	57	38	44	47	47	64	60	60
2			70	81	64	45	63	63	62	48	56	60	62	73	68	69
3				64	50	43	60	58	52	40	50	51	53	68	51	55
4					66	47	60	61	61	47	53	56	58	68	68	69
5						46	54	53	53	47	48	51	52	51	52	52
6							67	67	66	39	24	28	32	45	36	43
7								87	79	29	31	34	36	62	50	58
8									92	32	30	35	38	60	49	57
9										32	31	37	41	58	45	53
10											75	77	78	47	32	32
11												92	91	54	40	40
12													96	58	40	42
13														61	41	44
14															57	63
15																66

NOTE.--Footnotes appear at end of this table on page 27.

(Table continued on next page)

TABLE 5 (continued)

	Variable Numbers															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	66	35	26	28	-05	02	07	02	-07	-07	33	02	09	08	19	28
2	69	55	40	43	-01	08	13	06	-03	-14	49	13	19	12	21	39
3	62	42	30	30	00	07	13	02	02	-10	33	10	12	12	18	32
4	63	50	40	41	01	-02	16	04	-08	-13	45	03	16	12	16	35
5	51	57	51	52	-01	00	10	16	-10	-08	55	-02	23	10	12	34
6	49	34	29	32	-03	-01	08	02	03	-06	29	02	17	-07	10	19
7	68	50	41	42	-05	07	13	07	-03	-13	42	02	18	05	13	25
8	66	46	36	38	-07	06	11	07	-02	-10	40	02	15	02	15	25
9	60	46	36	39	-05	07	11	06	01	-09	39	02	16	04	11	26
10	39	38	31	32	04	-01	07	06	-01	-13	31	11	22	12	11	26
11	48	42	29	32	02	-04	12	05	-06	-14	37	07	18	14	16	37
12	51	46	34	39	-01	-04	13	06	-03	-15	39	09	24	15	13	37
13	52	50	29	43	01	-02	15	08	-01	-16	43	13	25	15	15	39
14	73	52	42	43	02	05	16	10	08	-16	41	16	17	14	24	32
15	56	39	28	30	02	01	13	-01	-08	-06	34	06	06	09	15	23
16	71	45	37	37	06	04	11	07	-01	-09	35	07	11	09	12	24

NOTE.--Footnotes appear at end of this table on page 27.

(Table continued on next page)

TABLE 5 (continued)

	Variable Numbers														
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
1	28	00	-05	-06	10	02	02	33	26	31	16	30	09	01	-16
2	33	04	-02	00	10	08	09	44	33	30	29	32	04	-04	-25
3	32	08	04	02	12	08	10	27	23	24	21	14	06	03	-17
4	31	-04	-03	-11	04	01	01	40	26	24	22	24	-02	02	-25
5	24	00	-03	-07	00	05	03	33	16	15	17	21	-10	-10	-25
6	13	04	05	-02	07	09	03	32	18	23	16	18	-08	-09	-12
7	24	08	07	00	13	11	08	35	28	36	17	25	-03	-08	-14
8	22	04	06	-01	12	11	10	35	28	36	16	27	-02	-05	-19
9	19	02	05	02	11	10	09	35	29	33	16	24	-03	-06	-21
10	27	00	-06	-05	02	03	02	25	11	09	28	16	-10	-08	-19
11	32	-02	-10	-04	03	07	07	26	12	10	34	14	-05	-07	-20
12	31	-02	-12	-08	05	08	09	30	14	11	35	18	-07	-06	-22
13	32	-01	-07	-05	06	10	07	33	17	11	38	20	-09	-08	-23
14	35	03	01	-03	12	09	11	37	28	29	35	29	03	-03	-26
15	26	-01	-06	-05	06	02	08	33	26	24	21	29	04	02	-20
16	24	03	-04	-02	08	04	06	34	30	33	23	26	00	02	-23

Note.--Footnotes appear at end of this table on page 27.

(Table continued on next page)

TABLE 5 (continued)

	Variable Numbers															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17		47	34	38	-01	02	14	04	01	-12	37	09	16	04	17	29
18			83	87	03	16	18	24	-02	-19	79	14	44	14	14	44
19				95	01	15	14	30	-02	-17	70	04	46	10	-04	27
20					-02	14	12	30	-07	-24	72	04	51	08	-04	30
21						32	22	13	28	20	-02	14	-06	-07	07	08
22							08	34	32	21	08	29	00	-03	-07	08
23								06	28	19	10	19	-02	-04	06	27
24									-02	02	13	09	01	-01	-02	11
25										20	-06	39	05	-20	06	12
26											-20	13	-21	-07	06	02
27												02	52	14	18	31
28													08	-07	20	25
29														-01	-03	20
30															13	-01
31																18

NOTE.--Footnotes appear at end of this table on page 27.

(Table continued on next page)

TABLE 5 (continued)

	Variable Numbers														
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
17	28	-02	-06	-01	12	04	01	32	26	34	24	23	02	-03	-19
18	36	10	04	-02	13	18	18	40	30	20	28	17	-16	-26	-29
19	26	02	06	-13	03	13	09	29	16	10	16	12	-16	-25	-22
20	26	03	05	-13	07	15	13	32	19	11	20	15	-16	-28	-24
21	05	16	03	20	17	12	08	13	10	01	15	06	-02	03	-06
22	-02	38	30	42	29	23	16	10	09	05	03	08	-09	-02	01
23	15	-01	01	06	05	07	09	23	21	16	24	18	-10	04	-02
24	-02	00	12	14	14	13	07	05	07	-07	07	07	-07	-05	-09
25	03	29	21	45	26	27	23	21	15	16	13	17	-03	09	00
26	-05	12	11	24	14	10	-03	00	01	00	04	-03	-02	11	03
27	34	07	04	-04	02	12	12	35	22	17	20	18	-09	-21	-23
28	20	30	19	29	28	20	13	18	30	21	30	16	05	03	-06
29	19	09	00	-05	08	15	13	18	-01	06	07	03	-09	-15	-14
30	03	05	01	-01	-09	00	23	01	02	08	07	02	03	05	-09
31	22	10	-01	08	07	13	06	20	18	14	22	15	-01	04	-09
32	61	09	06	08	14	11	12	30	31	23	34	16	-03	04	-24

NOTE.--Footnotes appear at end of this table on page 27.

(Table continued on next page)

TABLE 5 (continued)

	Variable Numbers														
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
33		11	08	06	15	09	16	24	19	13	32	13	-06	-06	-14
34			37	45	29	32	22	13	13	10	12	13	00	-12	-04
35				36	18	20	11	07	08	05	09	11	03	00	07
36					40	39	23	05	12	04	11	04	00	05	-02
37						45	22	16	22	05	15	05	-02	-03	-03
38							20	09	14	04	12	04	-04	-11	-08
39								11	07	09	18	04	-05	05	-12
40									48	28	38	53	-03	-09	-09
41										39	39	38	05	-04	-09
42											36	32	12	01	-13
43												28	-04	02	-09
44													02	-02	-06
45														-04	-14
46															-10

NOTES:

1. Decimal points have been omitted.
2. See Table 4 for identification of variables.

TABLE 6

Unrotated Principal-Axis Factor Matrix

Variable Number	Factor Number															h^2
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
1	72	-13	32	-06	05	06	06	03	-09	-12	07	-01	03	-02	-05	66
2	86	-06	18	01	02	08	11	05	-11	-08	10	-06	06	-04	-04	84
3	71	-04	22	03	15	12	02	-07	-06	-04	12	02	-03	14	01	64
4	81	-18	18	-01	02	02	16	-04	-03	-05	12	-08	09	-09	02	79
5	72	-16	-08	-07	07	-02	10	-04	07	-07	00	-06	18	-12	08	64
6	58	-05	17	-27	13	-17	-22	-08	12	06	-11	00	07	-02	03	50
7	76	-03	22	-40	12	-02	-14	-05	10	02	-01	09	-06	05	03	85
8	76	-04	28	-41	14	-04	-16	-07	15	08	-14	12	-02	-01	03	94
9	73	-04	23	-36	14	-06	-14	-06	14	12	-14	10	00	-04	07	83
10	60	-14	-10	43	19	-16	-10	07	05	06	-08	02	11	01	02	68
11	67	-18	-08	59	18	-07	-05	06	00	-01	-02	04	-01	00	05	88
12	72	-18	-10	57	18	-10	-07	08	00	07	-04	03	-03	-01	-01	95
13	75	-14	-13	54	17	-12	-07	08	02	06	-05	03	00	02	-01	95
14	81	-02	15	04	03	06	06	02	-05	00	02	-04	-10	18	-08	74
15	66	-10	24	-04	-04	07	20	04	-09	-03	16	-14	00	-13	01	63
16	72	-06	22	-11	01	03	20	02	-09	-01	10	-12	-08	-01	-04	66

NOTE.--Footnotes appear at end of this table on page 30.

(Table continued on next page)

TABLE 6 (continued)

Variable Number	Factor Number															h^2
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
17	76	-09	24	-08	07	-02	02	-05	-10	-04	02	-06	-15	14	-06	72
18	75	07	-51	-15	-12	07	04	-02	03	-03	00	-05	-06	04	06	88
19	61	-02	-63	-26	-06	-05	13	-01	-01	03	04	-04	-01	12	03	88
20	65	-03	-66	-26	-07	-04	07	02	-04	04	01	-02	-05	05	-04	95
21	03	36	00	11	02	-13	22	-05	02	-02	-03	-15	-03	-02	16	26
22	08	55	-12	-11	29	-07	25	08	00	-04	08	03	09	08	04	52
23	21	26	03	10	-22	-26	15	-18	13	09	07	-04	-14	06	24	40
24	14	20	-30	-10	19	-11	46	08	12	-22	-28	27	-06	03	-18	68
25	02	63	08	08	03	-19	-06	-09	-06	25	04	-23	03	15	-02	60
26	-15	32	17	05	05	-10	16	-12	10	-07	-02	-06	06	-04	25	30
27	64	-02	-46	-15	-15	13	-06	02	04	-02	03	-12	13	01	02	72
28	16	53	03	17	-10	-01	-02	-02	-11	00	-04	00	-01	20	-08	41
29	32	00	-46	-08	-03	06	-25	-08	-12	16	02	-14	05	00	-16	48
30	13	-10	-06	12	-02	49	11	33	30	16	14	12	09	-01	17	59
31	23	17	18	19	-25	31	-14	00	38	-36	-26	-29	07	18	-06	80
32	49	23	-09	22	-26	06	00	-41	-05	-07	00	27	07	-06	04	68

NOTE.--Footnotes appear at end of this table on page 30.

(Table continued on next page)

TABLE 6 (continued)

Variable Number	Factor Number															
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	h^2
33	44	16	-09	21	-24	19	-15	-36	-06	-18	17	22	03	-06	00	64
34	08	53	-04	-02	15	15	-14	13	-04	00	09	-01	15	-01	06	41
35	02	44	-03	-13	15	08	-07	10	02	-01	14	23	28	11	-02	42
36	-01	66	07	04	30	12	-02	02	00	00	02	-01	08	-04	02	56
37	15	53	00	-01	23	06	-11	-03	-13	-16	-04	-04	-26	-24	-12	56
38	15	46	-12	-01	22	11	-15	02	-01	-06	-09	-10	-11	-13	-01	38
39	14	32	-10	04	06	28	-03	02	14	27	10	02	-19	-12	-04	37
40	52	26	04	-01	-34	-21	-05	21	03	02	01	-06	09	-19	-04	60
41	39	33	14	-04	-36	-08	01	16	-04	-03	-07	10	-11	-08	-02	48
42	36	19	25	-10	-30	02	-06	11	-06	18	-05	09	-09	12	04	42
43	39	28	03	27	-28	-06	-03	07	07	04	-02	12	-12	02	-02	43
44	36	22	17	-02	-34	-20	02	34	02	05	-01	04	17	-12	-13	54
45	-05	-02	23	-01	-08	24	03	17	-46	02	-22	10	05	14	15	46
46	-10	02	32	15	-02	11	32	-26	20	32	05	00	11	03	-32	58
47	-31	-01	07	-06	04	-30	-22	16	17	-28	44	09	-12	15	-07	62

NOTES:

1. Decimal points have been omitted.
2. See Table 4 for identification of variables.

TABLE 7

Rotated Factor Matrix

Variable Number	Factor Number															
	I	II	III	IV	V	VI	VII	VII	IX	X	XI	XII	XIII	XIV	XV	h^2
1	23	-03	49	05	24	-01	13	44	24	01	-03	21	-07	02	-07	68
2	40	-01	48	11	34	02	15	45	28	07	-05	14	-01	02	-01	85
3	30	05	52	-03	25	08	08	37	09	04	05	16	00	14	02	63
4	39	-12	52	06	26	-03	14	36	28	07	-05	13	-04	-08	05	77
5	-53	-14	35	-02	21	-01	17	19	22	-04	-11	14	04	-14	06	64
6	33	02	38	-04	03	-13	04	09	21	-17	07	46	08	-04	-09	59
7	41	06	43	-04	01	-04	14	31	17	-06	10	56	-04	04	-06	84
8	38	05	48	-05	00	-07	14	22	17	-07	02	66	00	01	-11	93
9	38	04	46	-04	04	-10	11	18	16	-06	-01	62	03	-01	-06	83
10	36	-08	34	-03	62	-04	02	-09	05	-10	00	03	11	03	-05	68
11	36	-05	42	01	74	05	02	-04	00	-07	-02	-06	-02	06	-01	87
12	42	-04	42	01	76	-02	02	-07	02	-02	00	-03	-02	07	-05	95
13	46	-04	41	02	75	-01	05	-07	04	-04	02	00	03	09	-04	96
14	38	05	46	04	32	02	15	30	22	10	05	18	-05	25	-02	73
15	24	-03	41	12	22	-02	10	42	31	12	-06	09	-12	-08	08	62
16	31	04	42	06	18	-09	15	40	30	14	-01	16	-12	05	06	66

NOTE.--Footnotes appear at the end of this table on page 33.

(Table continued on next page)

TABLE 7 (continued)

Variable Number	Factor Number															h^2
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
17	33	06	51	01	20	-08	12	34	23	02	08	21	-13	21	-04	72
18	87	01	05	11	10	11	19	09	14	05	-01	10	-05	10	09	89
19	83	08	-08	00	01	-04	23	08	05	02	06	04	07	09	12	83
20	92	-03	-09	04	04	-08	22	08	08	07	03	04	-05	08	01	94
21	-03	24	04	14	02	00	13	-10	11	-03	-04	-10	12	02	34	26
22	10	42	-02	04	06	00	33	12	-07	-01	03	-04	36	01	26	52
23	09	04	18	30	01	-04	10	-18	10	02	18	06	-01	10	42	41
24	18	16	-10	-10	02	-06	74	-10	-10	01	-16	-04	04	06	00	68
25	-03	45	14	19	08	-07	-09	-13	14	05	19	-04	41	19	21	60
26	-24	17	08	08	-11	07	09	-10	03	-12	-04	-02	15	-07	35	30
27	77	-11	00	07	08	15	05	12	20	03	-03	07	05	02	00	70
28	02	31	05	30	08	14	10	-01	06	02	09	-04	26	32	04	41
29	60	04	-06	04	00	-02	-18	-04	06	07	06	-06	11	04	-21	47
30	07	-20	-15	-19	30	38	-04	15	-08	35	-14	21	02	-08	19	60
31	-05	-03	14	-02	08	64	08	-10	52	-10	-06	07	02	24	-05	80
32	35	-05	43	48	03	26	16	-07	-13	03	-03	-02	10	07	01	67

NOTE.--Footnotes appear at the end of this table on page 33.

(Table continued on next page)

TABLE 7 (continued)

Variable Number	Factor Number															h^2
	I	II	III	IV	V	VI	VII	VII	IX	X	XI	XII	XIII	XIV	XV	
33	34	-04	37	41	03	41	03	06	-13	00	09	-08	01	01	-08	63
34	07	39	-12	10	04	23	-03	14	-03	-04	00	08	36	-01	07	40
35	02	18	-13	05	-05	17	14	19	-18	-03	10	14	46	-01	01	41
36	-08	57	01	05	01	21	07	04	-06	00	-02	04	39	-02	12	56
37	08	68	07	17	01	13	10	03	01	-07	-02	01	-01	-06	-09	55
38	19	53	-03	04	03	18	02	-04	04	-07	-06	06	11	-02	-01	38
39	17	33	-02	04	07	22	-07	-06	-08	36	02	15	04	-04	07	37
40	25	03	05	47	23	-01	14	07	38	01	07	25	10	-07	02	59
41	09	12	03	49	12	06	20	10	21	05	02	27	-04	12	02	47
42	05	02	11	32	06	00	00	16	14	13	04	39	01	27	04	41
43	13	07	12	40	30	16	14	-09	08	10	11	15	01	18	05	42
44	02	-05	-06	42	25	-06	19	14	34	07	05	27	17	-03	-05	53
45	-20	-03	-05	13	03	-06	-14	32	-11	-04	-38	05	00	34	-05	46
46	-32	-08	32	-07	-10	-02	08	-14	06	53	04	-07	20	-02	-01	58
47	-28	-01	-23	-07	-01	03	04	09	-08	-26	61	-04	-10	-13	-02	62

NOTES:

1. Decimal points have been omitted.
2. See Table 4 for identification of variables.

Factor I. Time in Navy

Variables	Factor Loadings
2 Basic troubleshooting	.40
3 Computation	.30
4 Basic removal & replacement	.39
5 Records maintenance	.53
6 Radio and TT POMSEE	.33
7 Communications measurements	.41
8 Communications check and align	.38
9 Communications troubleshooting	.38
10 Radar POMSEE	.36
11 Radar measurements	.36
12 Radar check and align	.42
13 Radar troubleshooting	.46
14 Use of oscilloscope	.38
16 Use of VTVM	.31
17 Use of signal generator	.33
18 Pay grade	.87
19 Age	.88
20 Total Navy service	.92
27 ET experience	.77
29 Time in "A" and "B" schools	.60
32 Rating by immediate supervisor	.35
33 Rating by supervisor next in line	.34
46 Corrective maintenance work time	-.32

This factor has twenty-three loadings with magnitudes of .30 or greater. It appears to be a general maturity or experience factor with loadings on those measurements that tend to be time related. The largest loadings are on pay grade (.87), age (.88), and total Navy service (.92). Other measures of this time factor are ET experience (.77) and time in "A" and "B" schools (.60). Fifteen of the seventeen check list scores have loadings at or above .30 (ranging from .30 to .53) on Factor I indicating that with the passage of time ET's tend, on the average, to acquire experience and proficiency in most of the areas measured by the check list. Both of the supervisors' ratings have loadings on this factor. There is one relatively small negative loading (-.32); it is associated with work time in corrective maintenance as reflected in diary information. This indicates that there is a tendency for corrective maintenance to be done by lower pay grade, less experienced ET's. This is in agreement with other evidence in the study. It is interesting to note that variance in pay grade can be almost entirely accounted for by the passage of time. Pay grade has significant loadings on no other factor in this analysis.

Factor II. Proficiency in Mathematics

Variables	Factor Loadings
22 ARI score	.42
25 ETST score	.45
28 "A" school mark	.31
34 Powers of Ten	.39
36 Algebra	.57
37 Logarithms	.68
38 Trigonometric Functions	.53
39 Binary Arithmetic	.33

This factor has loadings only on tests and school marks. Five of the six Mathematical Achievement subtests have loadings greater than .30 on this factor. The one subtest not represented here is the one on square root. The largest loading is for Logarithms (.68). Both the Basic Test Battery Arithmetic Test and the Electronics Technician Selection Test (which has a substantial mathematics section) appear on this factor. "A" school mark has a modest loading of .31. No other measures of proficiency or job performance appear to be related to this factor.

Factor III. General Proficiency in Electronic Corrective Maintenance

Variables	Factor Loadings
1 Basic measurement	.49
2 Basic troubleshooting	.48
3 Computation	.52
4 Basic removal and replacement	.52
5 Records maintenance	.35
6 Radio and TT POMSEE	.38
7 Communications measurements	.43
8 Communications check and align	.48
9 Communications troubleshooting	.46
10 Radar POMSEE	.34
11 Radar measurements	.42
12 Radar check and align	.42
13 Radar troubleshooting	.41
14 Use of oscilloscope	.46
15 Use of VOM	.41
16 Use of VTVM	.42
17 Use of signal generator	.51
32 Rating by immediate supervisor	.43
33 Rating by supervisor next in line	.37
46 Corrective maintenance work time	.32

This factor has loadings above .30 on all of the check list scores, on supervisors' ratings, and on time devoted to corrective maintenance. It is similar to Factor I in many of its loadings but differs in that most direct measures of the time variable (age, length of service) have essentially zero loadings here and the time devoted to corrective maintenance has a positive loading while on Factor I it had a negative loading.

Factor IV. Proficiency in Use of Test Equipment

Variables	Factor Loadings
23 MECH score	.30
28 "A" school mark	.30
32 Rating by immediate supervisor	.48
33 Rating by supervisor next in line	.41
40 VOM Test	.47
41 VTVM Test	.49
42 Signal Generator Test	.32
43 Oscilloscope Test	.40
44 Schematic Reading	.42

This factor has loadings equal to or greater than .30 on all the subtests of the test equipment test, including schematic reading, on the Basic Test Battery Mechanical Test, on "A" school grades, and on supervisors' ratings. Factor IV is clearly a measure of proficiency in use of test equipment. Supervisors appear to give this factor substantial weight in rating the over-all proficiency of ET's. The fact that both MECH and "A" school grades appear on this factor suggests that it might be appropriate to consider MECH as one of the selection tests for electronics ratings.

Factor V. Proficiency in Radar Maintenance

Variables	Factor Loadings
2 Basic troubleshooting	.34
10 Radar POMSEE	.62
11 Radar measurements	.74
12 Radar check and align	.76
13 Radar troubleshooting	.75
14 Use of oscilloscope	.32
30 Time in "C" schools	.30
43 Oscilloscope Test	.30

The highest loadings on this factor are for variables 10, 11, 12, and 13, the check list variables directly associated with radar maintenance. Both the check list score on use of the oscilloscope and performance on the oscilloscope test are loaded on this factor

indicating that the oscilloscope is an important test instrument in radar maintenance. The "C" school time loading suggests that proficiency in radar maintenance is associated with "C" school attendance.

Factor VI. Proficiency Pay

Variables	Factor Loadings
30 Time in "C" schools	.38
31 Proficiency pay	.64
33 Rating by supervisor next in line	.41

This factor has only three loadings with the largest one on proficiency and the other two on time spent in Class "C" schools and the rating of the superior second in line of supervision. It is not surprising that proficiency pay is granted to those ET's who have had special maintenance training and who have favorably impressed their supervising officers.

Factor VII. Perceptual Speed

Variables	Factor Loadings
22 ARI score	.33
24 CLER score	.74

This is a poorly defined factor with only two loadings above .30. Both loadings are on Basic Test Battery timed tests where speed of perception may be important. Forms 5F and 6 of the Clerical Test are probably fairly pure measures of perceptual speed.

Factor VIII. Preventive Maintenance

Variables	Factor Loadings
1 Basic measurement	.44
2 Basic troubleshooting	.45
3 Computation	.37
4 Basic removal and replacement	.36
7 Communications measurement	.31
14 Use of oscilloscope	.30
15 Use of VOM	.42
16 Use of VTVM	.40
17 Use of signal generator	.34
45 Preventive maintenance work time	.32

This factor appears to measure basic aspects of ET performance. The ten loadings include nine check list scores which probably reflect more elementary aspects of ET job performance and one loading on work time devoted to preventive maintenance.

Factor IX. Basic Electronic Measurement

Variables	Factor Loadings
15 Use of VOM	.31
16 Use of VTVM	.30
31 Proficiency pay	.52
40 VOM test	.38
44 Schematic reading	.34

This factor has loadings on the check list scores associated with use of the VOM and VTVM, with VOM and schematic reading scores from the test equipment test, and with proficiency pay. The factor appears to measure basic ability to use test equipment, particularly the VOM. In this analysis, proficiency pay loads on two factors, Factor VI and this one. Apparently ability to make effective use of basic test instruments such as the VOM is related to the granting of proficiency pay. It should be pointed out that during the time survey data were being collected, proficiency pay was given only at the P-1 level and in this sample was ordinarily being received by relatively junior men.

Factor X. Assignment to Corrective Maintenance Tasks

Variables	Factor Loadings
30 Time in "C" schools	.35
39 Binary arithmetic	.36
46 Corrective maintenance work time	.53

This factor is not too well defined since it has only three loadings. It appears to indicate that, on the average, ET's who have had special "C" school training spend more time working at corrective maintenance than ET's who have not had such training. The binary arithmetic loading on this factor is thought to be coincidental; those who did well on the binary arithmetic test probably had received specialized training in that subject but also probably had had specialized maintenance training.

Factor XI. Assignment to Non-electronic Tasks

Variables	Factor Loadings
45 Preventive maintenance work time	-.38
47 Non-electronic work time	.61

Both loadings on this bi-polar doublet are associated with time reported in work diaries. It simply indicates that those men who spend more than the average amount of time on non-electronic duties spend less than the average time working at preventive maintenance.

Factor XII. Proficiency in Communications Equipment Maintenance

Variables	Factor Loadings
6 Radio and TT POMSEE	.46
7 Communications measurements	.56
8 Communications check and align	.66
9 Communications troubleshooting	.62
42 Signal Generator Test	.39

Four of the five loadings on this factor are on check list variables directly associated with the maintenance of communications equipment, and the fifth is on the signal generator portion of the test equipment test. The signal generator loading suggests that this test instrument is of considerable importance in the maintenance of communications equipment.

Factor XIII. Basic Mathematics (Arithmetic)

Variables	Factor Loadings
22 ARI score	.36
25 ETST score	.41
34 Powers of Ten	.36
35 Square root	.46
36 Algebra	.39

All of the variables in this factor except square root are included in Factor II. Factor XIII, however, does not include loadings on the more technical subtests of the Mathematical Achievement Test, such as logarithms and trigonometric functions. Since all of the tests represented on this factor contain arithmetic computations, this seems to be what the factor measures.

Factor XIV. Assignment to Preventive Maintenance Tasks

Variables	Factor Loadings
28 "A" school mark	.32
45 Preventive maintenance work time	.34

Since there are only two rather small loadings on this factor, it might be considered a residual. However, the loadings do indicate that there is some tendency for ET's who have done well in Class "A" school to be assigned to preventive maintenance tasks.

Factor XV. Education

Variables	Factor Loadings
21 GCT score	.34
23 MECH score	.42
26 Education	.35

Although this is another poorly defined factor, it seems to measure general education. Both the Basic Test Battery General Classification Test and years of education have loadings above .30 on no other factor in this analysis.